Northwest Alaska Climate Change Effects Table

The table below outlines some of the possible effects of climate change in Northwest Alaska. These effects are drawn from model data, expert observations, and the existing literature, and will be one of our primary references during the upcoming workshop, so please take some time to read through this table and fill it out. Indicate the level of importance (high, medium, or low) you would assign to each of these impacts, based on your own knowledge and experience. Feel free to leave fields blank if you are unsure about some categories. Use the comments section to clarify your responses and/or to indicate which parks/regions would be impacted.

This table is not all-encompassing. If you can think of anything that has been left out, please add it in your comments or at the bottom! We will be discussing this table at the final webinar this Wednesday.

Sector	Subsector	Potential Effects to Resources, Operations, and People	Level of impact (H/M/L)	Comments
Atmosphere	Greenhouse gases	**Deliberate biological and geological sequestration** may be implemented on federal-owned and other lands	LLLLL	
	Air temperature	**Air temperature increases** at an average rate of 1°F (0.56°C) per decade. For Bering Land Bridge, mean annual temps 10°F higher by 2080, with largest change in winter -- 8°F by 2040. 14°F by 2080.	HHHHH	
		Average annual temperatures shift from below freezing to above freezing in coastal areas by the end of the century.	HHHHHH	Nancy Fresco- remember that all of these can be viewed as cascading effects.
	Precipitation	**Average annual precipitation increases** through the mid- to late-21st Century. Relative proportions of moisture deposited as snow, ice or rain change as temperature increases.	MMHHH	Don C.-this will have a particularly pernicious effect re: access and subsistence activities.
		Arctic likely to experience drying conditions despite increased precipitation, due to higher temperature and increased rates of evapotranspiration.	MMHHH	Peter Neitlich- BELA has had huge fire episodes in past.

		More freezing rain events affect foraging success and survival of wildlife, travel safety, and utility transmission.	HHHH	
		Avalanche hazards increase in some areas with rising precipitation and rising winter temperatures.	LLLL	
	Stormy weather	**Lightning and lightning-ignited fires continue to increase.**	MMH	Lots of uncertainty here. Jennifer Barnes-if there is an increase, would influence fire prob, but how we determine this all v. uncertain. If it were to happen, impact would be high.
		Storm and wave impacts increase in Northern Alaska where land-fast sea ice forms later.	HHH	
	Air quality	**More smoke from longer and more intense fire** seasons results in seasonal and locally-severe smoke events, with respiratory and other associated health risks to populations.	LLM	
	Atmospheric contaminants	**Shifting contaminant distribution.** Dieldrin, p,p'-DDE, and mercury concentrations in some NPS areas in Alaska exceed established human health thresholds for humans, fish and mammals. Consumption advisories may be warranted to reduce or curtail consumption of affected species and age/size classes, especially for children and women of child bearing age.	HH	Peter-if temps go up and peat mobilizes mercury and there is more dissolved organic carbon available, could see the mercury issue coming to a fore.
		Increased contaminant bioavailability. Fugitive dust releases from mining operations near the NOAT, and transportation of ore concentrates through CAKR have resulted in elevated lead, cadmium, and zinc levels in plants and small animals in CAKR and in plants in the NOAT. Increased bioavailability of zinc dust (a known mossicide) with changing climatic conditions could markedly alter vegetation communities over large areas, and affect other species, subsistence use patterns and human health.	MMH	Bud-high for Cape Krusenstern but medium for everywhere else.
	Ice/Snow	**Snow and ice season is shorter with later onset of freeze-up and snowfalls and earlier spring snowmelt and ice breakup.**	HHHHH	

		Arctic snow cover declines, with higher average air temperatures, earlier spring thaw, and cryoconite deposition (atmospheric soot and dust)**.**	MHH	Nancy Fresco- lots of uncertainty here.
Cryosphere		**Lack of snow cover leads to deeper freezing of water in the ground or river beds resulting in more aufeis (overflow ice) on rivers and lakes and formations of pingos and yedomas on land.**	M	Nancy Fresco-uncertainty here as well.
		Undiscovered cultural resources are exposed as perennial snow and ice patches melt and recede.	LL	
	Sea Ice	**Shorter sea ice season, with less and thinner ice** complicates travel over ice, while easing boat travel through ice. Lack of sea ice in Spring-Fall impacts ecosystems (negatively for marine mammals/positively for some fish species), impacts subsistence access, increases risk and costs for marine mammal hunters. Adds energy to storm surges which increases erosion with high economic costs for community relocation.	HH	
		Seasonal reductions in Arctic sea ice enable more marine transportation and shipping accidents. As passenger and cargo traffic increases, the potential for accidents and the risk of spills contaminating NPS coastal resources increases.	MMHHH H	Wendy Loya-A spill would be significant. Peter Neitlich-O&G development/shipping major concern.
	Ice Roads	**Reduced winter transportation opportunities on frozen tundra** affect opportunities for natural resource development, access to subsistence sites, and travel between villages, spurring discussion of alternative transportation routes and easements.	MHHH	
	Permafrost	**Mercury and other pollutants are released into the aquatic environment** as the permafrost thaws, increasing contaminant exposure for wildlife and humans that rely on the marine ecosystem for food.	MH	
	Sea level	**Some coastal villages rapidly lose ground relative to sea level**, such as Shishmaref and Kivalina in Northwest Alaska. Erosion and subsidence are complicating factors.	HHHH	Peter-relocations will have effect on parks.

		Global average sea level is predicted to rise an additional 1-6 feet by the end of the 21st Century. However, regional trends in relative sea level vary widely with the effects of isostatic rebound, subsidence, warming, sediment deposition, etc.	MHHH	Bud- Thinks sea ice retreat and storm surges will have more impact than sea level rise.
Hydrosphere	Marine	**Increasing sea surface temperature affects ice-dependant species and their foods,** distribution and population dynamics of fish, seabird, and wildlife species.	MHH	Peter-although we don't have jurisdiction over these animals, this could increase hunting pressure terrestrially.
		Falling global phytoplankton concentration could reduce ocean productivity and CO_2 sequestration. Phytoplankton has declined at an average rate of ~1% of the global average per year over the last century. These fluctuations are strongly correlated with climate indices and sea surface temperature.	HHHH	
		Toxic marine algae and shellfish poisoning affects humans and marine mammals (e.g., PSP, ASP). Outbreaks are attributed to seasonal changes in coastal water temperature, nutrient enrichment, salinity, and ballast water discharge.	LLLM	Ken Adkisson-L/M in the near term; possibly greater over a longer time period.
		Ocean acidification affects plankton and benthic calcifying fauna (e.g., bivalves and echinoderms) in the Arctic more strongly than at lower latitudes, affecting food sources of fish, marine mammals such as walrus and gray whales, plankton feeding birds, and potentially the composition of the ecosystem.	HHH	Bud-has learned that there is already measurable acidification in Arctic waters (not yet published)
		Ocean acidification reduces sound absorption. Based on current projections of future pH values for the oceans, a decrease in sound absorption of 40% is expected by mid-century.	LMMM	Linda Jeschke-not yet an issue, but as shipping increases, it may be moderate.
	Estuarine	**Coastal erosion and sea level rise increase the frequency of saltwater flooding in some coastal areas**, infiltrating freshwater coastal lagoons, marshes, and groundwater with salt.	HHH	Ken Adkisson-Shifts in coastal biotic resources and perhaps human populations.
	Freshwater	**Ponds shrink as thermokarst drainage occurs in some permafrost areas**. Others form as ground ice thaws and ground surface subsides, but many drain through surface or subsurface discharge as thaw depth increases.	MMH	Linda Jeschke-Locals have already commented on change in bird populations and decreased diversity re: changing ponds.

				Peter/Ken-this is a vital sign that ARCN monitors. Lots of forming and drying of lakes. The effect is real, but what is the impact?
		Drainage from thawing waste and sewage dumps contaminates rural water supplies. Two-thirds of Alaska's village residents still do not have access to sanitary means of sewage disposal or adequate supplies of safe water.	MMHH	Linda Jeschke-already a problem in many villages; has seen many instances.
	Ground stability	**More constructed assets fail or require repairs.** Many locations in Alaska that are underlain by permafrost are susceptible to thaw damage. Modeling by University of Alaska researchers suggests that projected climate changes could raise future infrastructure costs about 10%.	LLMHH	Wendy-because we can actually somewhat control this, she tends to rank it lower than she would a natural phenomenon. Don C.-still an issue for communities/ lower income areas. Peter-such fixes could drain park budgets.
		Coastal erosion claims both natural and cultural resources and constructed assets. Coastal erosion is proceeding at an average of 20" (0.5 m)/year in some areas of CAKR and in BELA. Coasts in some communities are eroding much more rapidly than this (tens of meters per year). Some constructed assets, historic and prehistoric sites will no longer be sustainable and will require triage to determine which to repair, relocate, document, or abandon. Large areas of Alaska's coastal parks lack needed surveys for archaeological sites.	HH	Don C.-this has been an issue for a long time, but even now, we don't have the resources to mitigate it, let alone do the surveys. Ken Adkisson- Cultural resources potential loss could be mitigated through expanded archeological data recovery
Lithosphere		**Burials and other human remains are exposed in some areas** as cultural sites thaw and erode due to changing hydrology, ice, snow, and permafrost thaw.	H	
	Soil	**Soil moisture declines** due to rising soil temperature, increased evapotranspiration, thawing permafrost, and natural drainage.	MH	
	Rock and gravel	**Demand for rubble and rock increases**, as it is required for repairs and new construction, roads, and community relocation.	MHH	Ken-Can be addressed by planning and human action. Linda Jeschke- people are already scrambling in Kotzebue

				for gravel.
Biosphere	General	**Ecological "tipping points" are likely to result in rapid change**, when conditions exceed physical or physiological thresholds (e.g., thaw, drought, water temperature).	LHH	Wendy Loya-not sure that we will hit thresholds in the next several decades.
	Vegetation	**Increased growing season length**. Modeling predicts that the mean number of frost free days for the Boreal and Arctic bioregion will increase between 20 and 40 days by the end of the century.	LLH	
		Increased agricultural production in Alaska. A longer growing season and Alaska's abundant summer sunlight provide new agricultural opportunities in some areas.	LLLM	Peter-right now USDA considers Nome to have 5 frost free days. It would take a lot to become an agriculturally significant area. Linda Jeschke- would be good if people did more local gardening. Only a few greenhouses.
		Large-scale landcover changes occur over periods of years to decades. Some terrestrial vegetation models suggest potential for large-scale conversion of low tundra to shrubs, then to conifers, and from conifers to deciduous forests, or perhaps to grass. Other models indicate increasing lichen, decreased sedges, and increases to deciduous and evergreen shrubs.	HHH	Peter-ranked as high mainly because of shrub increase. Doesn't see that reflected much in this document. This is what we mean by "landcover change". Loss of tundra habitats would create challenges for ungulates.
		Tree species and vegetation classes shift as species typical of lower altitudes and latitudes expand into higher areas.	LHHH	Linda Jeschke- large impacts on all wildlife.
		Mountain and arctic ecosystems could change substantially within 50 years, and conditions become unsuited for some native species. **Some rare species could become endangered and endangered plants species may go extinct as conditions change.**	MHH	
		Atypical outbreaks of pests and plant diseases occur more widely, increasing fire hazards and hastening decline of	LLMH	Peter-lots of uncertainty. Linda Jeschke-prevalent south of

		native and familiar species.		us, may happen here.
		Invasive exotic species and native species from other areas expand into parks. It becomes easier for invasive species that are already adapted to such conditions, to survive, reproduce and expand into available habitat as native species become increasingly stressed by changing conditions such as rising temperature and declining soil moisture.	LH	Peter-low, but again, lots of uncertainty. Ken-high. Could be a major concern over longer time periods, might be addressed on a regional or landscape scale
		Shrubs and trees expand further into tundra primarily along hillsides and valleys. Some scenic tundra vistas become thick with deciduous trees and shrubs, obscuring wildlife observations from visitor centers and park roads.	LH	
		Black spruce may expand or contract, expanding under warming conditions coupled with increasing fire interval – or contracting as underlying permafrost soils thaw and fire frequency increases.	LMM	Peter-too much uncertainty to say for sure.
	Fire	**Fire increases in boreal and tundra ecosystems.** Model simulations show a warming climate leads to slightly more fires and much larger fires, as well as expansion of forest into previously treeless tundra. Flammability increases rapidly in direct response to climate warming and more gradually in response to climate-induced vegetation changes.	MHH	
		Wildland fire hazards increase, affecting communities and isolated property owners.	LLMM	
		Fire-related landcover and soil changes include vegetation population shifts, major permafrost thawing, soil decomposition, and surface subsidence.	HH	Peter-Fire resets the successional trajectories toward graminoid dominated systems.
	Wildlife - General	**Changes to the terrestrial and aquatic species compositions in parks and refuges occur as ranges shift**, contract, or expand. Rare species and/or communities may become further at risk, and additional species could become rare. Some early-succession species will benefit from changes.	MHH	

		Parks and refuges may not be able to meet their mandate of protecting current species within their boundaries, or in the case of some refuges, the species for whose habitat protection they were designed. While some wildlife may be able to move northward or to higher elevations to escape some effects of climate change, federal boundaries are static.	MHH	
		Changes in terrestrial and marine wildlife distributions affect visitor experiences and subsistence throughout the region.	LHH	
		Some species suffer severe losses. An analysis of potential climate change impacts on mammalian species in U.S. national parks indicates that on average about 8% of current mammalian species diversity may be lost. The greatest losses across all parks occurred in rodent species (44%), bats (22%), and carnivores (19%).	HHH	
		Predator-prey relationships may change in unexpected ways.	MH	
		Migratory routes and destinations will change for some species (e.g., wetlands, open tundra, snow patches).	HHH	Peter-esp. yellow-billed loons
	Wildlife - Birds	**Arctic and alpine breeding birds' breeding habitats will be reduced** or eliminated as trees and shrubs encroach on areas currently occupied by tundra. 72% of Arctic and alpine birds are considered moderately or highly vulnerable to the impacts of climate change.	HHH	Peter-yellow billed loons and montane nesting shorebirds main issues.
		Boreal forest birds expand into the arctic as climate changes, causing new avian communities to develop.	MMH	
		Millions of geese could lose almost half of their breeding habitat due to a predicted change in vegetation in the Arctic from tundra to taiga and boreal forest.	H	
		Waterfowl shifts occur as coastal ponds become more salty in some areas.	HHH	
		Productivity of nesting shorebirds may increase if they are able to change their migration and nesting schedules to coincide with the time when the most insects are available.	M	Peter- Melanie Flame should contribute to this; Peter will send her the questionnaire.

		Predation on ground nesting birds could increase if alternate prey (lemming) abundance declines with changes to weather and tundra habitats.	M	
		Coastal seabirds show medium or high vulnerability to climate change due to their low reproductive potential and their reliance on marine food webs that are also threatened by climate change.	H	
	Wildlife - Marine Mammals	**Ice dependant Arctic marine mammals are affected by sea ice decline, including walrus, ice seals, and polar bear.** Beluga and bowhead whales may move into territory previously unavailable to them.	HHH	
		Increased ambient sound affects marine mammals. Reduction in sound absorption and increased human vessel traffic due to receding sea ice and tidewater glaciers may affect marine mammals that rely on echolocation for communication and prey location.	MM	
		Polar bear hazards increase in coastal communities. As polar bears have increasingly difficult times accessing prey and finding appropriate shelter for reproduction and protection, they may be more likely to approach villages and encounter humans.	LMMH	
	Wildlife – Caribou/Reindeer	**Caribou and reindeer health may be affected** by changes in temperature and precipitation patterns, increases in insects and pests known to harass caribou and reductions of succulent forage.	MH	
		Earlier green-up could improve caribou calf survival due to more forage available to females during calving and lactation.	MH	Ken-Might be offset by stochastic events such as ice storms.
		A loss in tundra plant species diversity could affect caribou and other wildlife. For example, forbs that are selectively grazed upon by caribou during lactation or lichens used as over-wintering food.	HHH	
		Caribou may suffer heavy losses, if vegetation glazes over following rain-on-snow events, preventing successful feeding during cold weather.	HHH	Peter would include muskox in this area as well.

	Wildlife - Moose	**Predicted shifts in forest community could result in less suitable habitat for caribou, but potentially increased habitat for moose** in Yukon Flats National Wildlife Refuge and similar habitats.	MM	
		Climate change could decouple timing and synchrony of birth, hindering moose calf survival.	M	
	Wildlife – Small mammals	**Fire may help yellow-cheeked vole populations** in the short-term, as it creates new burrowing habitat and aids in the growth of forage.	L	
		Reduced snow cover reduces survival of voles and other subnivian species, due to increased predation and cold stresses, with changes in small and large mammal predator-prey relationships.	M	
	Fisheries	**Marine regimes could shift from benthic (bottom) to pelagic (open water) species.** Late ice retreat supports benthic organisms. When there is no ice, or early ice retreat, a mostly pelagic ecosystem is supported.	H	
		Commercial fisheries shift. Changes in ocean community organization in the Bering Sea caused by warming climate and associated loss of sea ice alter availability of snow crab and other fisheries resources.	MH	Linda Jeschke- Coastal communities depend hugely on salmon and whitefish.
		Ocean acidification affects fisheries. Pteropods and crustaceans foods of salmon may decline with ocean acidification.	HH	Peter-this could put more pressure on terrestrial food sources.
		Fish diseases such as *Ichthyophonus* increase with rising water temperatures. Models indicate that temperature increase in streams in south-central Alaska will be around 3°C, a change that could increase disease in fish.	MH	
		Some existing salmon waters may become unsuitable for migration, spawning and incubation.	H	
		Fish habitats in some permafrost-dominated areas may be degraded by thaw-related hill slumps and massive sediment input into rivers.	M	
	Invertebrates	**Marine intertidal environments change** and may become more susceptible to exotic marine species.	M	

		Exotic pests, diseases and their vectors expand into Alaska from warmer areas, and endemic pests expand as host species are stressed by climate change (e.g., bark beetles, budworms, ticks, lice, West Nile virus, Lyme disease, hantavirus, HP avian influenza, **plague, vespid [yellowjacket spp.] outbreaks, black flies, mosquito swarms, bott flies, etc.)**,	H	
		Intensified management expands. Some local residents and management agencies may advocate managing for new species that have the potential to replace diminished subsistence hunting, trapping, and fishing opportunities, and for intensified management of native species.	MHHH	
	Subsistence, Fishing, and Hunting	**Altered migration patterns make hunting more challenging.** Migration patterns of terrestrial animals are predicted to change as temperatures, precipitation patterns, and vegetation availability change.	HHH	Ken-depends on the resource.
		Marine subsistence becomes more challenging. As sea ice conditions change, hunting for marine mammals is becoming more dangerous and costly. Marine mammals may follow sea ice retreat, altering their distribution and taking them out of range for some hunters.	HHHH	
		Community resources available for subsistence activities decline as increased storm surges, and permafrost erosion compound effects of change to relative sea level, impacting infrastructure in Native Alaskan communities, in some cases requiring relocation of entire communities.	HHHH	Ken- This is a big concern for coastal parks and potentially those just inland such as KOVA and NOAT
		Large-scale physical and biological changes across broad landscapes affect abundance and condition of wilderness-associated resources (glaciers, tundra, boreal forest, wildlife, scenic vistas, river flows, access routes, etc.)	LH	Ken- you could have a total transformation from tundra to desert and still have pristine wilderness
	Wilderness	**The scientific community becomes increasingly interested in wilderness sites** for a variety of inventories, monitoring and research projects, some of which involve highly technical instruments, mechanized access, and long-term installations.	HHH	Peter-already a hugely contentious area and source of conflict.

Other Human Uses and Values		The changing biophysical landscape, and increased human activity to research, monitor, and respond to threats associated with climate change affect key wilderness values such as naturalness, wild-untamed areas without permanent facilities opportunities for solitude, etc.	M	
		Tourism expands at higher latitudes. The effects of these changes will depend greatly on the flexibility demonstrated by institutions and tourists as they react to climate change.	LH	Ken- This could have positive as well as negative effects and may depend heavily on economic conditions.
	Tourism	**Tourism season lengthens** with increasing temperatures and more snow-free days. Some visitor activities increase, while others (e.g., snow sports) may decline.	LL	
		Landscape-level changes affect visitor experiences as iconic scenery changes, and access for subsistence, hiking, boating, etc. changes with vegetation, soil, and water conditions. Some changes are conducive to visitation, and some are not, depending on local conditions and visitor expectations.	LM	
		Visitor use patterns shift as tour operators seek to provide visitors with more opportunities to experience increasingly uncommon glacier scenery. Cruise ships and day tour operators may shift some itineraries away from the parks they've traditionally visited, or seek more opportunities to shift itineraries deeper into the parks. Land based operators may press to bring groups further into the park through aircraft, airboats, snowmobile tours, off road vehicles (ORVs), and road extensions.	LLH	Linda-not much tourism here because there are few facilities.
		Visitor demand for new interpretive/education media products, publications and services that address changing climate will increase, putting pressure on existing programs and staffing as a result.	LMHHH	John Morris-anticipates an increase in virtual interpretive services/requests. Others agree.
		More cruise ships pass through the Bering Straights as ice-free conditions become more reliable.	LH	
		Coastal tourism destinations are affected by increase coastal erosion, and losses of natural and cultural resources, natural routes of access, and built infrastructure.	LH	

		Safety hazards develop, expand or are recognized in relation to climate change, such as thin ice, erratic flooding, changing fire and smoke hazards, slope failures (mudslides, landslides, tsunami hazards), and expansion of more disease organisms (fish, wildlife, and human) and their vectors into Alaska.	MH	Peter-both snow machining and boating have become more dangerous.
	Other Hazards	**The predictive uses of traditional ecological knowledge will change**, as unprecedented changes develop for weather, freeze/thaw conditions, plants, animals, fire, etc.	HHHH	
	Customary and Traditional Knowledge	**Natural resource development and economic activities expand in Alaska** with increasing global demand for energy and resources to supply rising global population.	HHHHH	
	Resource and Economic Development	**Developmental pressures increase as direct or indirect effects of reduced snow and ice cover**. These include expanded global and regional transportation systems and their associated infrastructure (e.g. opening of the Northwest Passage due to reduced sea ice, permanent roads to replace ice roads), increased demand for natural resource development (construction materials – especially gravel and rock, energy and minerals for infrastructure repair, replacement, and expansion), shifting agricultural production zones, community resettlement and other population shifts.	MH	
		Infrastructure development expands along Alaska's coasts and Interior to provide needed services, facilities, and transportation systems for other expanded activities.	MH	
		Damage to roads, buildings, and other infrastructure increases due largely to permafrost thaw (but also from storms, floods, and landslides) adding 10% to 20% by 2080.	HH	Ken-could especially be a problem under flat or declining budgets.

		Relocating indigenous communities represents a large social burden, not just financial cost for governments, but also impacts the communities themselves, potentially resulting in loss of integral cultural elements such as access to traditional use areas for subsistence activities, loss of history and sense of intact community, and potential loss of social networks and extended kin support. Significant increases in social pathologies such as alcoholism and domestic violence may be anticipated. In addition, tremendous stresses will be placed on traditional means of conflict resolution. In addition multiple strains will be placed on local governance and delivery of services. Finally, state and federal governments will have huge additional burdens placed on them as they try to provide relief from the impacts of climate change (flooding, destruction of infrastructure, high demands placed on social services and so forth). Response to climate change will require enormous pressures for integrated and efficient bureaucratic structures.	HHH	Ken-What is the NPS role in this?
		Fuel and energy prices increase substantially as carbon mitigation measures are implemented (sequestration, carbon caps, offsets, etc.). Costs of transporting fuels to remote locations by barge, ice roads, aircraft, etc. also becomes more challenging and costly.	HHHH	Bud-anticipates that there will be increased demand for alternative energy sources.

Peter- would like to see in greenhouse gases area something that reflects the fact that as permafrost and peat start to decompose, there will be a large release of methane which is much more potent than CO2 (as far as greenhouse gases go). Bud thinks we need a new row in greenhouse gases area called “increased releases”.